FTD-HT-23-305-69

FOREIGN TECHNOLOGY DIVISION

CHARACTERISTICS OF ELASTICITY OF TUNGSTEN, MOLYBDENUM, NIOBIUM, AND THEIR ALLOYS AT 20 TO 2,700°C

By

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FTD-HT- 23-305-69

EDITED TRANSLATION

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English Pages: 6

Source: AN UKRRSR. Dopovidi Seriya A. Fizyko-Tekhnichni ta Matematychni Nauky, (Academy of Sciences of the Ukrainian SSR. Reports, Series A. Physical, Technical and Mathematical Sciences), 1967, Nr. 10, pp. 917-921

Translated Under: F33657-70-D-0607

UR/0441/67/000/010

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FTD-HT- 23-305-69 Date 9 March 1970

CHARACTERISTICS OF ELASTICITY OF TUNGSTEN, MOLYBDENUM, NIOBIUM, AND THEIR ALLOYS AT 20 TO 2,700°C[1]

V. A. Dreshpak

(Presented by G. S. Pisarenko, Academician of the Academy of Sciences of the Ukrainian SSR)

Results of experimental moduli of elasticity of the first and second kind for tungsten, molybdenum, niobium, and their alloys are presented for a wide temperature range (up to 2,700°C) in vacuum. These temperatures are considerably higher than those at which these characteristics were determined hitherto.

With the development of new branches of technology and the rise in the magnitude of the working parameters of contemporary machines, the study of the elastic characteristics of high-melting materials used in construction is becoming important.

In the Strength of Materials Institute of the Ukrainian SSR Academy of Sciences, a method was developed and a device was constructed, the UP-6, that uses the dynamic method of resonance frequency of lateral and rotational vibration to determine Young's modulus and the shear modulus of high-melting materials in a range of temperatures from 20 to 2,700°C [1].

This article presents results of research on the elasticity moduli of tungsten, molybdenum, niobium, and their alloys.

Footnote No. 1 may be found on page 7.

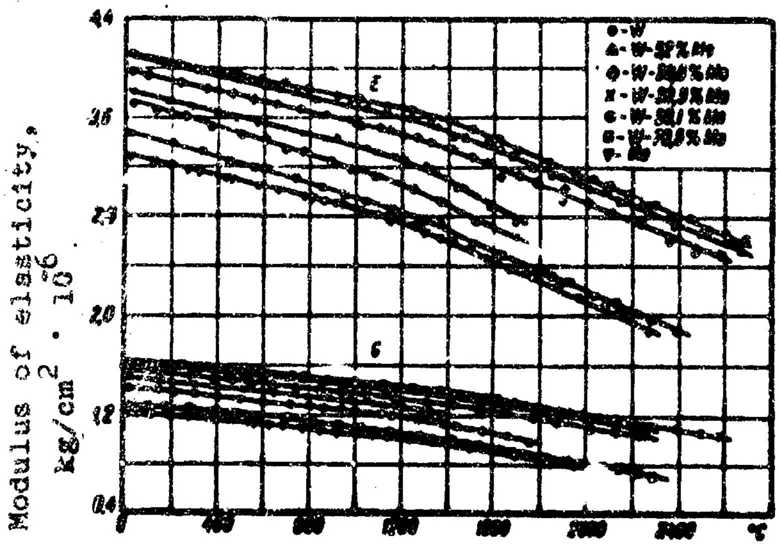

Figure 1

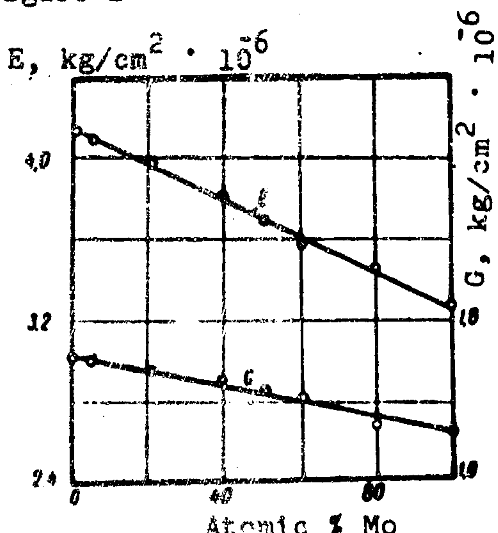

Figure 2

The samples (W, Mo, and their alloys) for the tests were prepared from rods of the metal which were smelted in a vacuum-arc furnace with a consumable electrode. Then the ingots were heated to 1,400 to 1,600°C and subject to plastic deformation in several stages (total deformation 60 - 80%) with each subsequent remelting.

In Figure 1, the temperature dependence of Young's modulus and shear modulus of tungsten, molybdenum, and alloys of tungsten respectively, are 5.2, 20.8, 39.5, and 79.5% molybdenum are presented.

Experiments at standard temperature have shown that value size of the elasticity modulus is proportional to the percentage content of tungsten in the alloy (Figure 2).

The linear dependence of Young's moduli on the component content in these alloys is explained by the fact that, since tungsten and molybdenum have the same structure of their crystal lattices (the difference in the parameters is only 0.57%), they can form an uninterrupted series of solid solutions.

The temperature dependences of Young's modulus for tungsten, molybdenum, and their alloys form a declining curve. At a temperature of about 0.5 T_{melt}, Young's modulus begins to change more intensely. The shear modulus varies less rapidly with the temperature change.

The temperature dependence curve of Young's modulus clearly shows two different rates of change of the decreasing modulus, with a more rapid slope appearing around 1600°C.

The temperature dependences of elasticity moduli for other metals, determined by a resonance method, usually have a similar pattern -- the curve begins to slope more rapidly at about 0.5 T_{melt} [2].

The above mentioned changes of slope are probably caused either by a change in the interatomic bond forces in the crystal lattices or by the relaxation processes which may take place during loading of the material in a certain temperature range.

Keeping these assumptions in mind, we may expect a less rapid change of the moduli during their measuring at higher frequencies, since under those conditions the effect of the relaxation processes is less noticeable. This reasoning can be demonstrated by a comparison of the temperature dependence of Young's modulus, obtained by us by a resonance method (frequency about 5 kHz), with the same dependence obtained by means of a pulse method (frequency about 5MHz) [3]. The temperature dependence obtained at higher frequencies does not have the characteristic change of slope at about 0.5 T_{melt}, although it is curvilinear as a whole (Figure 3). Therefore, the assumption that the relaxation processes taking place in materials at temperatures about 0.5 T_{melt} definitely affect their elasticity should be considered as more credible.

Niobium distinguishes itself from other refractory metals by a series of special properties. A relatively low specific gravity, satisfactory formability and machinability, and also high strength and

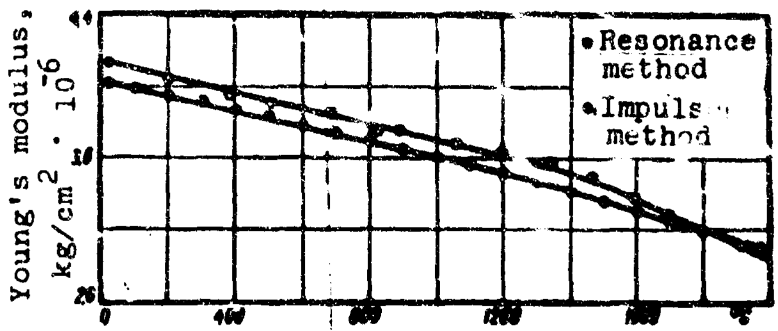

Figure 3

plasticity in a broad range of temperatures, make it possible to consider this metal as a construction material.

Among the faults of niobium, one should mention its tendency toward intense oxidation at higher temperatures. However, there are reasons to believe that alloys of niobium will not have these faults.

According to [2, 4] Young's modulus for niobium at room temperature is (1.06 to 1.6) · 10^6 kg/cm^2, and the shear modulus is (3.8 to 8.82) · 10^5 kg/cm^2. Such a divergence is due to the fact that various researchers used metal of varying degrees of purity. It is also the result of methodological peculiarities of various experiments.

Keeping in mind the aforementioned facts, and also the limited temperature range of previous experiments, we determined Young's modulus and shear modulus for niobium by electron-beam fusion at temperatures from 20 to 2,200°C (Figure 4).

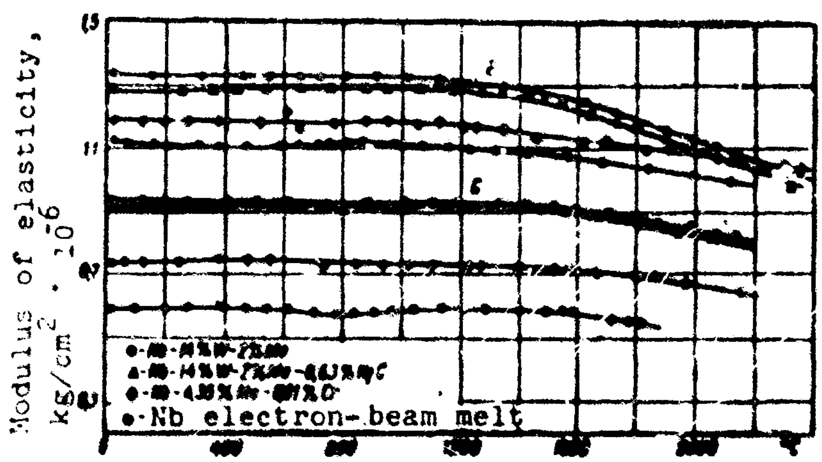

Figure 4

The moduli of elasticity of niobium, in contrast to other metals, hardly change until 1,400°C. Some decrease of Young's modulus is noticed in the interval between 300 and 500°C; thereafter, the modulus assumes its previous magnitude. Beginning at 1,400°C, Young's modulus slowly decreases. The nature of this anomaly has not yet been fully explained. There are assumptions [4] that a similar phenomenon is connected with the presence of impurities in niobium (usually oxygen) which at higher temperatures form solid solutions strengthening the interatomic bonds of niobium. This is confirmed by the solubility of oxygen in niobium in the solid state.

Oxygen has a similar influence on titanium and the analog of niobium, tantalum. At an oxygen content of 0.1 at. % the modulus of elasticity of tantalum at room temperature is $1.8 \cdot 10^6$ kg/cm^2. As the oxygen content increases to 2.5%, it becomes $2.0 \cdot 10^6$ kg/cm^2; the shear modulus of technically pure tantalum at standard temperature is $3.84 \cdot 10^5$ kg/cm^2, and an admixture of 4.5% oxygen raises this modulus to $4.5 \cdot 10^5$ kg/cm^2.

According to the data of M. G. Lozinskiy and O. Ye. Fedorovskiy [2], the logarithmic curve of the decrement of vibration damping in niobium has a maximum near 300°C, which indicates processes of penetration of atoms of impurities into the crystalline lattices at that temperature. At a temperature of 400 to 500°C, in niobium there takes place a decomposition of a solid solution of nitrogen, and this causes the maximum of the logarithmic decrement of vibration damping and Young's modulus to decrease.

In the study of complex niobium alloys, there is a great interest in the study of the influence of admixtures on the magnitude of atomic interaction in solids. We have studied the elasticity characteristics of the following alloys based on niobium:

Nb -- 4.35 Mo -- 0.01Cr; Nb -- 14W -- 2Mo and

Nb -- 14W -- 2Mo -- 0.83HfC.

The alloys were obtained by a double electron-beam remelting of sintered rods in a vacuum. Ingots, 50 mm in diameter, were forged at 1200°C into bars. Owing to the small deformation (60%), full recrystallization did not take place, and the original crystalline structure was preserved.

The temperature dependences of Young's and shear moduli for the alloys at 20 - 2400°C are shown in Figure 4.

The addition of tungsten and molybdenum to niobium increases its modulus of elasticity, but hafnium carbide slightly decreases it. Due to a high niobium content in the investigated alloys, the changes in the elasticity characteristics occurring in the niobium alloys with increasing temperature were similar to those taking place in pure niobium.

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UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Foreign Technology Division Air Force Systems Command U. S. Air Force	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

CHARACTERISTICS OF ELASTICITY OF TUNGSTEN, MOLYBDENUM; NIOBIUM, AND THEIR ALLOYS AT 20 TO 2,700°C

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Translation

5. AUTHOR(S) (First name, middle initial, last name)

Dreshpak, V. A.

6. REPORT DATE 1967	7a. TOTAL NO. OF PAGES 6	7b. NO. OF REFS 4
8a. CONTRACT OR GRANT NO. F33657-70-D-0607 b. PROJECT NO. 72301-78 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) FTD-HT-23-305-69 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	

10. DISTRIBUTION STATEMENT

Distribution of this document is unlimited. It may be released to the Clearinghouse, Department of Commerce, for sale to the general public.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Foreign Technology Division Wright-Patterson AFB, Ohio

13. ABSTRACT

The article presents the results of experiments determine the modulus of elasticity and rigidity of tungsten, molybdenum, niobium and their alloys at 20-2700 degrees centigrade. Ingots of the above metals and their alloys were heated to 1400-1600 degrees centigrade and deformed with 60-85 percent reduction. The modulus of elasticity and rigidity of specimens prepared from the ingots were determined by means of a dynamic method using a resonant frequency of the transverse and torsional vibrations It was found that the modulus of elasticity and rigidity of tungsten, molybdenum, and tungsten-molybdenum alloys decreased with increasing temperature. The modulus of elasticity and rigidity of niobium remained practically constant to about 1400 degrees centigrade beyond which they began to decrease with increasing temperature. Alloying with tungsten and molybdenum increased the modulus of elasticity and rigidity of niobium alloys. Orig. art. has: 4 figures. (AP7032420)

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Elasticity						
Elastic Modulus						
Molybdenum Alloy						
Niobium Alloy						
Tungsten Allcy						

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